APPLICATION OF THE DPSIR FRAMEWORK FOR SIBERIAN COMMUNITIES

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Abstract

The development of Siberia is a priority for the Russian government as it has great economic potential. However, the benefits for local populations are unclear, as economic expansion affects traditional livelihoods and social development. The challenges faced by the local population are, to some extent, relevant for all traditional communities in the world. While a huge amount of research is devoted to ongoing socio-economic processes in developing countries, about the transformations in Russian Siberia. In this paper DPSIR approach used to identify driving forces, pressures, states, impact and responses within Siberian communities. New indicators were proposed for a policy analysis.

Keywords: DPSIR Framework, sustainable communities, Siberian environment, sustainability measures

I. Introduction

Although there are several approaches for conducting these studies, a commonly used method is the DPSIR framework developed by the European Environment Agency in 1999 [13]. The DPSIR (The Driving forces - Pressure - State - Impact - Response) is a conceptual framework for describing the interactions between society and the environment. The flexibility is one of the main advantages of the DPSIR. It allows building the framework addressing the problem or management concern [71]. This advantage is embodied through a step-by-step approach to build the DPSIR. The initial step towards the creation of the DPSIR is identifying main concepts and indicators for specific problem.

II. Methods

DPSIR method highlights cause-and-effect relationships and systematises information to solve environmental problems. It was an extension of Pressure-State-Response (PSR) model developed by Organisation for Economic Cooperation and Development [43]. This technique appeared as a response to the need to analyse a Social–Ecological System (SES). According to [11] SES is a type of complex adaptive system. These systems comprise many interdependent parts that interact in ways that give rise to many patterns that cannot be predicted. The SES concept developed at works [10, 45]. According to [5] DPSIR or its modifications help to formalise relationships between society's adverse effects on the environment, and responses to such effects. Moreover, DPSIR shows these relationships in its dynamic. The ability to see the dynamics of the process is important for

adaptive management. It can help to monitor and evaluate the current situation to progressively implement a project. The DPSIR framework was applied for many projects and communities around the world and has been repeatedly improved and modified.

However, there are still vast geographical and conceptual areas that have hardly been studied in terms of adaptive management of SES. Recently, some increased in the use of the DPSIR method can be observed. Figure 1 shows a distribution of published papers by six countries during last 10 years (2012-2022). Three countries are northern states since part of their territory is located beyond the Arctic Circle; another group represented by three southern countries.

Despite varieties of approaches to the application of the DPSIR framework many studies have been carried out in relation to the southern communities, or at countries belong to Global South according to the UN classification [69]. There may be several reasons. A significant part of the world's population living at southern communities. Many countries at South and Southeast Asia are part of the so-called the Pacific Ring of Fire [40] is a region around much of the rim of the Pacific Ocean where many volcanic eruptions and earthquakes occur. This increases the number of natural disasters happened in this region and induced the vulnerability of communities. All these require additional measures to reduce risk and maintain resilience. Another reason may lie in the additional risks caused by the developing nature of the economies of these countries, which are in an active process of industrialization [41]. It can create an additional burden on ecosystems and risk for local communities. Given the two circumstances described above, international organisations, including the UN pay specific attention to the countries, united by the South-South development strategy.

Meanwhile the northern regions of our planet are experiencing no less pressure due to climate change. For example, over the past 30 years the Arctic has warmed more than three times faster than the world average [34]. The fragility of local ecosystems and their susceptibility to temperature changes; increased vulnerability of infrastructure, most of which is built on permafrost, the layer of which is constantly decreasing; life and cultural characteristics of the local population, adapted to harsh weather conditions that can be destroyed due to climate change – all these define the vulnerability of northern communities in the Arctic and Siberian regions [68]. Facts above describe the severity of the problem for communities in the northern latitudes makes a comprehensive assessment of the natural, social and economic development of this region extremely relevant. It is necessary to consider the actual lack of relevant research in such places like Siberia. Such study would fill gaps in scientific knowledge for these areas and enrich existing methodology of decision supporting tools with new concepts and methods from the northern perspective.

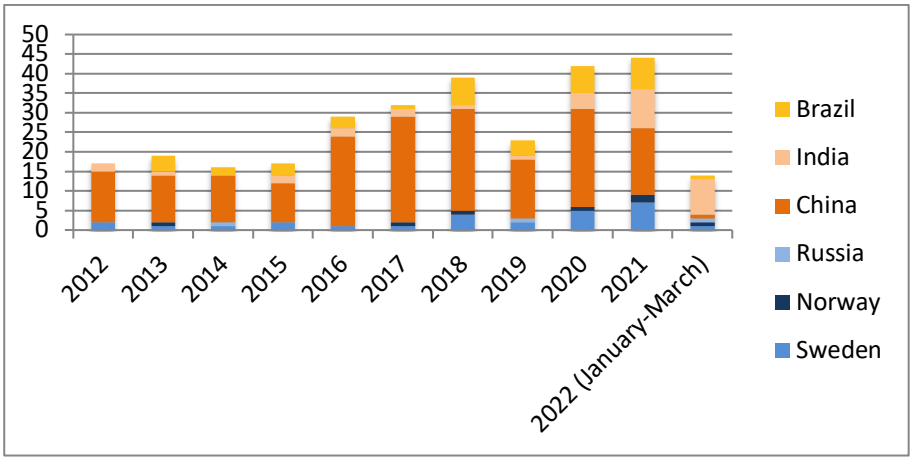

Figure 1: *The search results at Google Scholar, Russian Scientific Electronic Library and China National Knowledge Infrastructure (number of published papers regarding application of DPSIR framework by selected countries by years)*

In this paper DPSIR framework will be applied to Siberian region. Driving forces will be identified within current socio-economic and environmental situation; Pressures and States will be studied based on environmental reports for Siberian region during the last three decades; scientific

literature review will be done for identify the impact of adverse impacts; Russian legislation system will be analysed to study responses proved by the government. Further, based on the DPSIR analysis new indicators will be proposed for complex policy related study of communities in Siberia.

III. Results

Driving forces

Driving forces in the DPSIR model are fundamental human needs in the society, which cause different activities and lead to environmental problems. In the context of community vulnerability to climate change Driving forces can be described as human activities which aggravating climate change by inducing variability of ecosystems. Changes in climate lead to further variability of ecosystems, which creates a "vicious circle", with human activity as a prime Driving force. Further main Driving forces in Siberia are defined.

Siberia is the main Russian region for mining production [6, 28, 29]. Kemerovo oblast called the forge of Russia. That is why industrial raw material extraction and its processing (machine tool building, locomotive manufacturing, steel production, chemical production etc.) are the main economic drivers in this region and determine Siberian Federal District as a national centre of heavy industry [7]. Economic growth leads to intensification of raw materials production and the development of heavy industry in Siberia and as a result affects local ecosystems and the ability of communities for sustainable development and growth. The main centres of mining in the Siberian Federal District are located unevenly. It is important to note that some of the industrial centres are located on the territory of permafrost. This region has traditionally been a centre for the extraction of coal and other minerals. A new promising direction is the extraction of hydrocarbon raw materials, which is just beginning in this region. Significant prospects for increasing the Russian raw material production are associated with further study of the oil and gas potential of Siberia [62]. In addition to heavy industry, agriculture is well developed in the Siberian Federal District. It is another important driver of the economy. The share of the Siberian Federal District in the total volume of agricultural production of all agricultural producers in Russia (agricultural organisations, individual entrepreneurs) in the first quarter of 2021 amounted to 10.7% [59].

Despite the development of the heavy industry and agriculture, all regions of the Siberian Federal District have a negative balance of migration within the country for a long time. The Siberian Federal District occupies 25.5% of Russia's territory and accounts only for 11.7% of the country's population [59]. Only the city of Novosibirsk has a positive migration trend. In the regions, the outflow of the population is partly compensated by incoming migrants from Central Asia. Despite the positive impact of these migrants on the demographic situation of the region, they cannot compensate for the outflow of the local population. Migrants also aggravate ethnic problems because of different cultural values. Due to the low level of professional qualification, they can little contribute to modernisation of heavy industry. Such negative tendencies decrease ability for collective response and its adaptive capacity. Many experts [61] consider the impact of migration on the demographic situation, economy and culture to be negative. And in the opinion of other scientists [58, 38], even the local population is replacing by migrants. At the same time, some experts [63, 74] point to the low level of education and professional qualifications of newcomers, their cultural priorities and poor knowledge of the Russian language. These migration processes reduce the ability of communities to cooperate and increase their vulnerability to climate risks.

Another ethno-demographic problem is the presence of indigenous populations, living in traditional habitats and have a traditional lifestyle. They are among the most socially vulnerable groups of the population. According to [51] their places of residence are characterised by a low level of socio-economic development, lack of social and transport infrastructure. The problems of education of migrants and indigenous peoples directly affect human capital and the ability of peoples to adapt to climate change and conduct effective climate change policy. One of the main

tasks is the preservation and development of the national system of education of the indigenous peoples of Siberia, integration of migrants into multinational communities of Siberian Federal District. According to [67] the main problem of education is the lack of qualified personnel, as well as ignoring the cultural and historical characteristics of different nationalities, which reduces the effectiveness of educational programs. At the same time, part of the researcher emphasises the reluctance of the indigenous peoples themselves to receive education due to traditional lifestyle, which doesn't require high education [18, 39], while some other scientists see the problem in the preparation of educational programs [67, 57].

Complex infrastructure problems aggravate the vulnerability of local communities to climate change. In [19, 75, 24] described a low level of gasification of the Siberian regions, problems of energy efficiency, the absence of central heating in the regions of the Far North, which makes these territories dependent on the so-called Northern delivery of energy resources. However, it is necessary to note the additional effect of climate change that is associated with the possibility of using the Northern Sea Route more actively in the future for the transportation of hydrocarbons [62].

Pressures

These Driving forces create Pressures on ecosystem processes. Pressures in the DPSIR model show the degree of exploitation of resources. In general, the Siberian Federal District suffers from a complex degradation of ecosystems, including air, water, soil, flora and fauna [73, 60, 55, 21]. However, the pressure on some areas of the ecosystem is especially high, which, for example, makes the region a national leader in air pollution. These problems will be discussed below.

The high proportion of raw materials extraction and heavy industries cause the Siberian Federal District became a leader in terms of air pollution among other Russian regions. In particular, the Krasnoyarsk Krai, Novosibirsk city, Omsk city and Kemerovo Oblast took the last lines of the national environmental rating [21]. Another acute problem is the disposal of production waste. More than half of all Russian waste was generated in the Siberian Federal District [55]. The largest amount of waste (86.8%) is generated during the extraction of raw materials, mainly represented by products of mineral processing [21]. Many experts [48, 20] notify the lack of a systematic approach to the separation, collection and disposal of waste, including these containing toxic components, increasing the environmental pollution.

In addition to the factors mentioned above agriculture and forests clear-cutting contributes to the deterioration of the ecosystems of the Siberian Federal District. The problem of soil pollution is extremely acute in the region, both due to the development of the raw materials industry and due to the use of fertilisers in agriculture [56]. According to [8] the resource potential of Siberia forests has been significantly undermined by depleted forest management in the last century. Also, many authors [12, 2] point out that the problem of deforestation is connected not only with clear cutting, but also with fires, where the human factor and "consuming" attitude to the environment play an important role.

State

Adverse human activities create Pressures, which lead to the variability of the State of the environment and increase the Exposure of climate factors to local communities. [4] describes these factors as external to the community system, while Sensitivity is an internal factor of community vulnerability. According to [52, 2] two categories of changes in the State are observed in the territory of the Siberian Federal District: man-made changes and climate changes. Some authors [72, 49] claim that man-made changes in the State of ecosystems prevail in the region. While others [8, 65] believe that even though man-made transformations of ecosystem's State remain leading positions, at the beginning of the 21st century, the priority has shifted to the synergy of climate and man-made changes. Man-made changes are associated with a decrease in the forest fund, polluted territories,

degradation of agricultural land, as well as mining areas. Since the beginning of the century, the Siberian Federal District has been the leader in terms of the deforestation resulting both from clear cutting and from wildfires [35, 49]. The high industrialisation of the region leads to changes in the state of soils, including in areas of Arctic soils [65]. The area of the most valuable soils for agricultural use in the Krasnoyarsk Krai and Altai Krai is decreasing. Up to 50% of all chernosems of the Siberian Federal District is concentrated in these two regions [56].

According to [65, 25] the man-made changes described above are only intensifying due to increasing changes in climate. Climate changes are observed at the whole territory of Siberian Federal District, such as an increase in temperature, changes in precipitation, a decrease in permafrost cover in the North of the region, where much of the heavy industry infrastructure is located. The scenario made by [25] of the most intensive increase in greenhouse gas emissions by the middle of the 21st century in comparison to the end of the 20th century will lead to an increase in summer air temperature by 1.0-1.5°C, and in the South by 2-3°C. Precipitation in summer in the North and in the centre parts of Siberia may increase by 10-20%, and in the South decrease by 5-10%. In winter, in the northern and central regions, air temperature may rise by 5-8°C, in the southern part - by 3-5°C. The increase in precipitation in the winter season in most of the district is expected to be in the range of 20-40%, and on the coast of the Arctic ocean - 50-80%

Impact

The consequences of these Pressures and changes in the State lead to an Impact on local ecosystem and community wellbeing. Main Impacts on Siberian communities can be divided into three categories: economics Impact, environmental Impact and social Impact. Currently, there is no unequivocal opinion in Russian science regarding the impact of climate change on the communities of the Siberian Federal District. Some researchers [30, 50] see climate change as an opportunity, mainly due to increase in the period of use of the Northern Sea Route, availability of raw materials, development of tourism due to milder temperatures, reduction of central heating costs. While others [47, 36, 33] highlight its disruptive impact on community functioning, and believe that the benefits of new opportunities will not offset the damage from climate warming, especially for communities whose economic activity: takes place in permafrost regions; associated with the agricultural sector and fisheries; depends on "Northern delivery"; as well as for the indigenous peoples of the North, who are engaged in traditional economic activities. The distribution of hazardous natural phenomena across the territory of Russia largely depends on the relief and the degree of proximity to large water areas [46]. The largest number of hazardous phenomena in recent years has been observed in the Siberian Federal District [14]. The geographical position, flatness of the territory of Western Siberia creates prerequisites for the penetration of air masses both from the South and from the North. From the West, the territory of Siberia is bounded by the Ural Mountains, and its eastern part in the cold half of the year is subject to the influence of the western spur of the Siberian anticyclone. All this leads to instability in the atmosphere. At the same time, in the South of Western Siberia, according to the results published in 2017 [54] the risk of heavy and prolonged precipitation has significantly increased in recent years. All this leads to great destruction from natural disasters, for example, flooding of residential buildings.

In addition to the uneven distribution of natural disasters depending on the landscape, it has seasonal features. According to [33], at the beginning of the 21st century, in the spring-summer period, almost the entire territory of Western Siberia is covered by warming. In the cold season, this process is disrupted. In autumn, the temperature begins to decrease, and in winter this process is clearly expressed in the South of the region (including the Tomsk Oblast), while in its northern part the trend is stable positive. In summer, there is a possibility of dry periods, as there is an increase in negative extremes of precipitation. This is also facilitated by the fact that in the South of the region there is an increase in the likelihood of high temperatures (above 30°C) and a decrease in wind speed

[33]. This is especially notable in the South of Western Siberia and in the Tomsk Oblast and Altay Krai (the region engaged in agriculture, which certainly has a negative impact on the economic and social development of local communities). In addition, there is a threat to the local population, flora and fauna due to the increased number of forest fires. While many communities in the South of the region depend on agro-industrial production, the population of the northern communities is often engaged in fishing [66]. The climate change described above affects the region's aquatic systems, fisheries and aquaculture, and endangers the communities that depend on them and their livelihoods.

In the light of the above changes, particular concerns are caused by disruptive tendencies in the regions of the Far North. In the regions of the Far North, climate change has contributed to the intensification of new natural hazards, which can be called geocryological [3]. These include processes and phenomena that are associated with the melting of ice and have an adverse impact on the environment. One of the problems that have become aggravated in recent years is the destructive impact of permafrost melting on infrastructure. Many industrial and residential buildings, oil rigs, pumping stations and pipelines, roads, bridges, runways in the northern regions are built on permafrost and are designed for operation in a certain range of changes in external conditions. Melting of permafrost can affect many logistics processes, for example, "North delivery".

All these changes become a serious economic challenge for the region. The development of non-environmentally friendly, extractive industries in the region, as well as high climate risks, may reduce the potential for attracting investment. The development of the ESG approach in the world practice also reduces the attractiveness of many companies in the Siberian Federal District for potential investment. At the same time, according to [9, 53] in Siberia, the development eco-products market based on the agricultural production of the Altai Mountains is planned. This new market can potentially create new "green" development opportunities for this region. This potential is based on the ecosystem richness of this region. The nature of the Altai Mountains has diverse natural potential. Its flora and fauna make it possible to classify Altai as one of the world's centres of biodiversity concentration on the planet.

Resposes

Resolutions, National Strategies, Federal and regional laws, decrees of the Government of the Russian Federation - all these are the main sources of information about the Responses in the field of reducing the vulnerability of communities to climate change. However, as [42] mentions in the legislation of the Russian Federation the prevention of climate change is not established as a goal of legal regulation. Climate change combating policy is reflected in the following fundamental documents: [17, 25]. In addition, there are several Federal laws aimed at protecting forests, waters and lands from pollution. However, the Strategy for Social and Economic development of Siberia until 2020 [27] did not reflect the problems of vulnerability to climate change. All measures to combat climate change can be divided into three categories: prevention, mitigation and adaptation; and two areas: environmental and socio-economic. Table 1 provides a list of examples of various measures and legislative acts in specific categories.

Table 1: *Examples of legislations and other measures to reduce the vulnerability of the population to climate change in Russia*

	Environmental	Socio-economic
Prevention	Fedortsova and Sidorenko, 2017; (PJSC Gazprom Neft is implementing the Corporate Biodiversity Conservation Program based on the List of flora and fauna species that are indicators of the sustainable state of marine ecosystems	Federal Law on Fire Safety of December 21, 1994 (as amended on June 11, 2021) On Fire Safety. Federal Law No. 82 of April 30, 1999 (as amended on July 13, 2020) On

	in the Russian Arctic zone.) Federal Law on Fire Safety of December 21, 1994 (as amended on June 11, 2021) On Fire Safety. List of requirements and mandatory measures to improve, protect land and protect soil from winds, water erosion, 2019. (Federal service for veterinary and phytosanitary supervision Order July 8, 2019, no. 662)	Guarantees of the Rights of Indigenous Peoples of the Russian Federation.
Mitigation	Federal Law of June 11, 2021, No. 175 On the development of agriculture. Federal Law No. 254 dated July 31, 2020, On the Peculiarities of Regulating Certain Relations for the Purpose of Modernising and Expanding the Main Infrastructure and on Amending Certain Legislative Acts of the Russian Federation. Federal Law on Production and Consumption Wastes of June 24, 1998 (as amended by Resolution of the Constitutional Court of the Russian Federation of July 19, 2019, N 30-P)	Guidelines for organising the preparation and support of a flood-hazardous period on the territory of a constituent entity of the Russian Federation (approved by the Russian Ministry of Emergency Situations on November 10, 2021). Oltyan, et al., 2021 Implementation of the Sendai Framework for Disaster Reduction in the Russian Federation. Kharitonov, et al, 2021 Problems and prospects of socio-economic development of rural areas: a regional aspect
Adaptation	The National Action Plan for the first stage of adaptation to climate change for the period up to 2022 was created, which was created for various sectors of the economy. Order of the Ministry of Economic Development of the Russian Federation of May 13, 2021, N 267 "On approval of methodological recommendations and indicators on adaptation to climate change».	Order of the Federal Agency for Ethnic Affairs of Russia dated November 17, 2020, N 142 On approval of the Guidelines for public authorities of the constituent entities of the Russian Federation "On the social and cultural adaptation and integration of foreign citizens in the Russian Federation". The National Action Plan for the first stage of adaptation to climate change for the period up to 2022 was created, which was created for various sectors of the economy.

Further main features of prevention, mitigation and adaptation measures held in Russian are considered. In general, measures to prevent the impact of climate change on the communities are mainly based on the protection of the local population from natural and man-made disasters, as well as the protection of the rights of vulnerable population; local authorities are developing guidance to prevent soil destruction and the reduction of the forest fund. Despite the fact, that guarantees of the rights of indigenous peoples are described in the Federal law there are need for additional support of these communities. According to [64] there are some measures of support on reindeer husbandry, as this is the main area of traditional business of the indigenous peoples of the

North of Russia. These measures include: the support for reindeer breeding as a separate area of subsidies, including the purchase of breeding stock. Grants for the development of a family farm, purchase snowmobiles etc.

Measures to mitigate climate change impact include increasing the preparedness of the population for natural disasters, implemented as part of international initiatives such as: "My city is getting ready!" [1]. In addition, special attention is paid to rural communities. All regions of the country are divided into four types with the first type, where the rural population prevail over urban population, and the fourth type, where the urban population prevails. It should contribute to targeted assistance within the framework of the implementation of the Strategy for the Sustainable Development of Rural Territories of the Russian Federation until 2030 [44]. The waste management reform aims to harmonise the sorting and disposal of various types of waste. Also, it is planned to increase opportunities for waste processing [22]. [23] considers measures to create infrastructure in specially protected natural areas and reserves, as well as on the territory of Lake Baikal.

Comprehensive adaptation measures have only just begun to be implemented in Russia. Their development is associated with the publication of The National Action Plan for the first stage of adaptation to climate change for the period up to 2022. It is supposed that this plan evolves in 2022 and beyond to create comprehensive climate change adaptation measures.

IV. Discussion

DPSIR indicators

Based on main DPSIR concepts for Siberian region, indicators for the application of the DPSIR framework are proposed at Table 2.

Table 2: *DPSIR indicators for Siberian region*

DPSIR component	№ of Indicator	Indicator
Driving forces	D1	Gross regional product and its % of GDP
	D2	Population
	D3	Financing of geological exploration (billion rubles)
	D4	The share of agricultural production from the all-Russian (%)
	D5	The share of extraction of natural resources from the all-Russian (%)
	D6	Number of indigenous people
	D7	Share of communities employed in agriculture (%)
	D8	The level of gasification of the population (%)
	D9	Urbanisation rate (%)
	D10	Number of industrial centres in permafrost areas
	D11	Migration rate
Pressures	P1	Greenhouse gas emission by per sector
	P2	Non-greenhouse gas emission by per sector
	P3	Solid waste generation rate m3/ person
	P4	Spread of fires (hectar)
	P5	Applied chemicals (kg active ingredient / hectar)
State	S1	Temperature variability
	S2	Changes in the forest fund (m2)
	S3	Precipitation variability
	S4	Permafrost variability
	S5	Degradation of agricultural land (%)
	I1	Grain yield

Impact	I2	Human Development Index
	I3	Number of households depend on North Delivery
	I4	Number of households affected by disasters
	I5	Tourism development
	I6	Fishery development
	I7	Development of reindeer breeding
	I8	Infrastructure development
	I9	Investments
Responses	R1	Number of normative acts and regulations
	R2	Share of recycling and neutralisation of waste
	R3	Human capital development
	R4	Dynamics of modernisation
	R5	Dynamics of gasification
	R6	Dynamics of deforestation

The DPSIR can be a useful tool for creating comprehensive plans for the development of the region. The creation of DPSIR for community-based management in climate risk in Siberia needs a set of special indicators. The study needs to start with the defining of the study area, which is a difficult task due to the vagueness of the term Siberia. To solve this problem, it is proposed to proceed from the modern administrative-territorial boundaries of the regions of Russia, due to climate change policy remain state-led in Russia. Also, it is proposed to consider ethnic and climatic factors. After studying the materials, it becomes clear that the territory of the Siberian Federal District, including the Tyumen Oblast, which has a trans-boundary position, has boundaries that correspond to the historical definition of Siberia. Ethnic processes in the territory of this region led to the formation of a special sub-ethnos of Siberians, which can also serve to determine the study area within one sub-ethnic group. As for the climatic features, the longitude location of the region makes it possible to study the impact of climate change on the activities of communities in the Arctic, sub-Arctic and Continental climatic zones, as well as strategies for interzonal interaction. Based on DPSIR concepts a set of indicators was determined for the quantitative assessment of the components of the DPSIR. All this work is a preparatory stage for the creation of the DPSIR for community-based management in climate risk. Further research could be carried out in the field of studying the main indicators and identifying the relationships between the main elements of the DPSIR.

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